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(54) **TANDEM DRIVE AXLE SYSTEM WITH SIMPLIFIED REAR AXLE**

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CPC ..... **B60K 17/36** (2013.01); **B60K 23/08** (2013.01); **F16D 2011/004** (2013.01); **F16D 2500/10425** (2013.01)

(58) **Field of Classification Search**

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See application file for complete search history.

(56) **References Cited**

U.S. PATENT DOCUMENTS

1,975,208 A	10/1934	Hastings et al.
2,046,262 A	6/1936	Grover
2,144,359 A	1/1939	Bryan
4,046,210 A	9/1977	Nelson
5,711,389 A	1/1998	Schlosser
2006/0272866 A1	12/2006	Ziech
2010/0248888 A1	9/2010	Hamperl et al.
2013/0017927 A1*	1/2013	Morscheck et al. .... 477/35

\* cited by examiner

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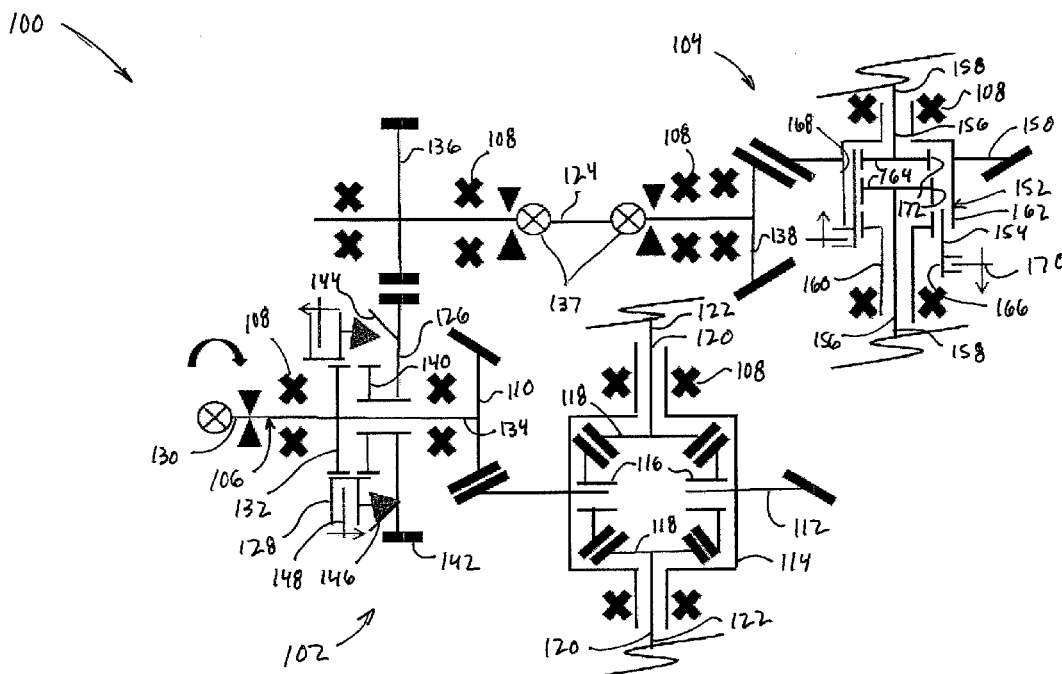
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(57) **ABSTRACT**

A tandem axle system has a forward rear tandem axle and a rear rear tandem axle. A rear differential case, a first axle half shaft and a second axle half shaft extending from the differential case. The first axle half shaft has a first set of teeth and the second axle half shaft has a second set of teeth. The rear differential case has a set of teeth. A clutch collar is provided which has teeth on a surface. The teeth selectively engage with the first axle half shaft teeth and the second axle half shaft teeth. The teeth selectively engage with the teeth on the rear differential case.

**11 Claims, 6 Drawing Sheets**



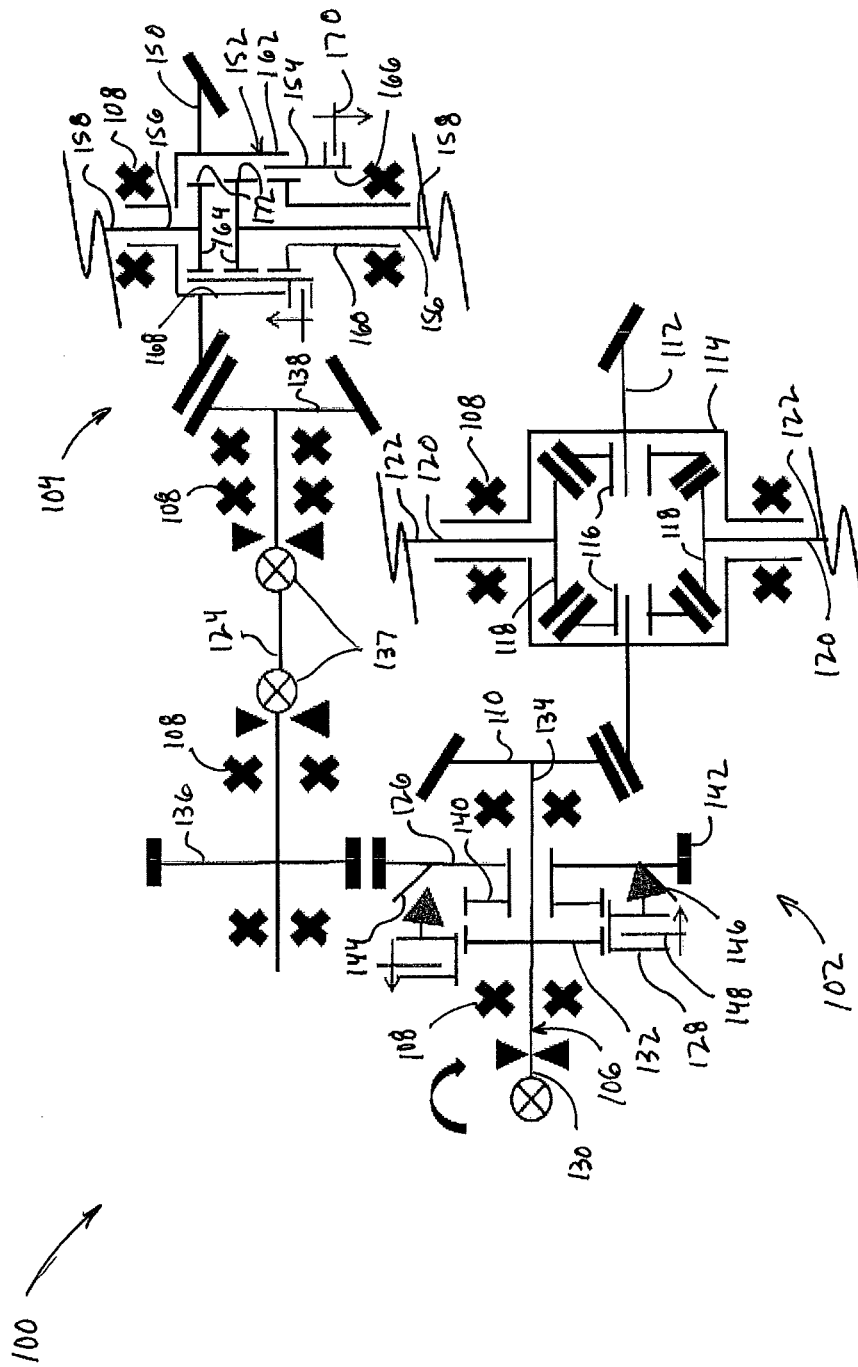


FIG. 1

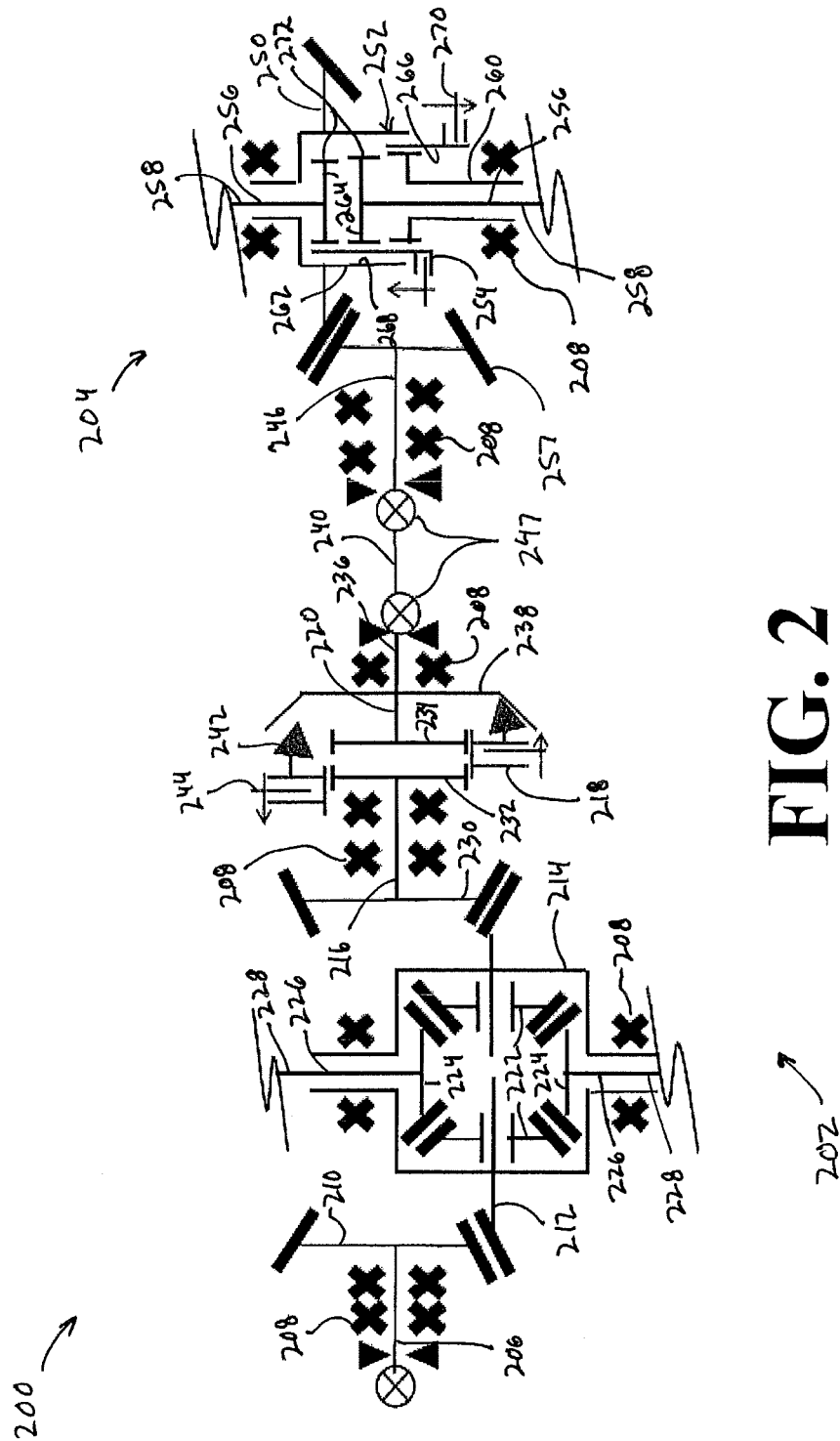


FIG. 2

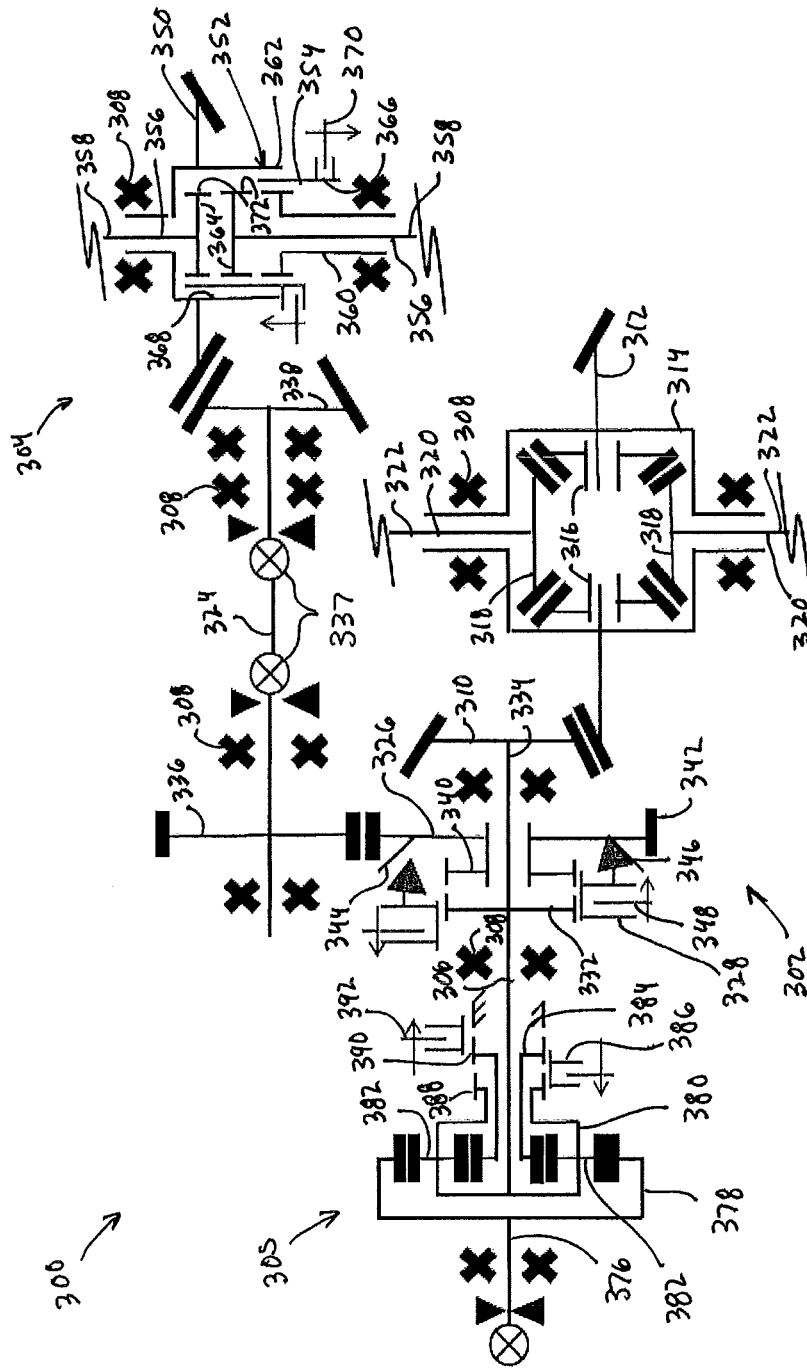
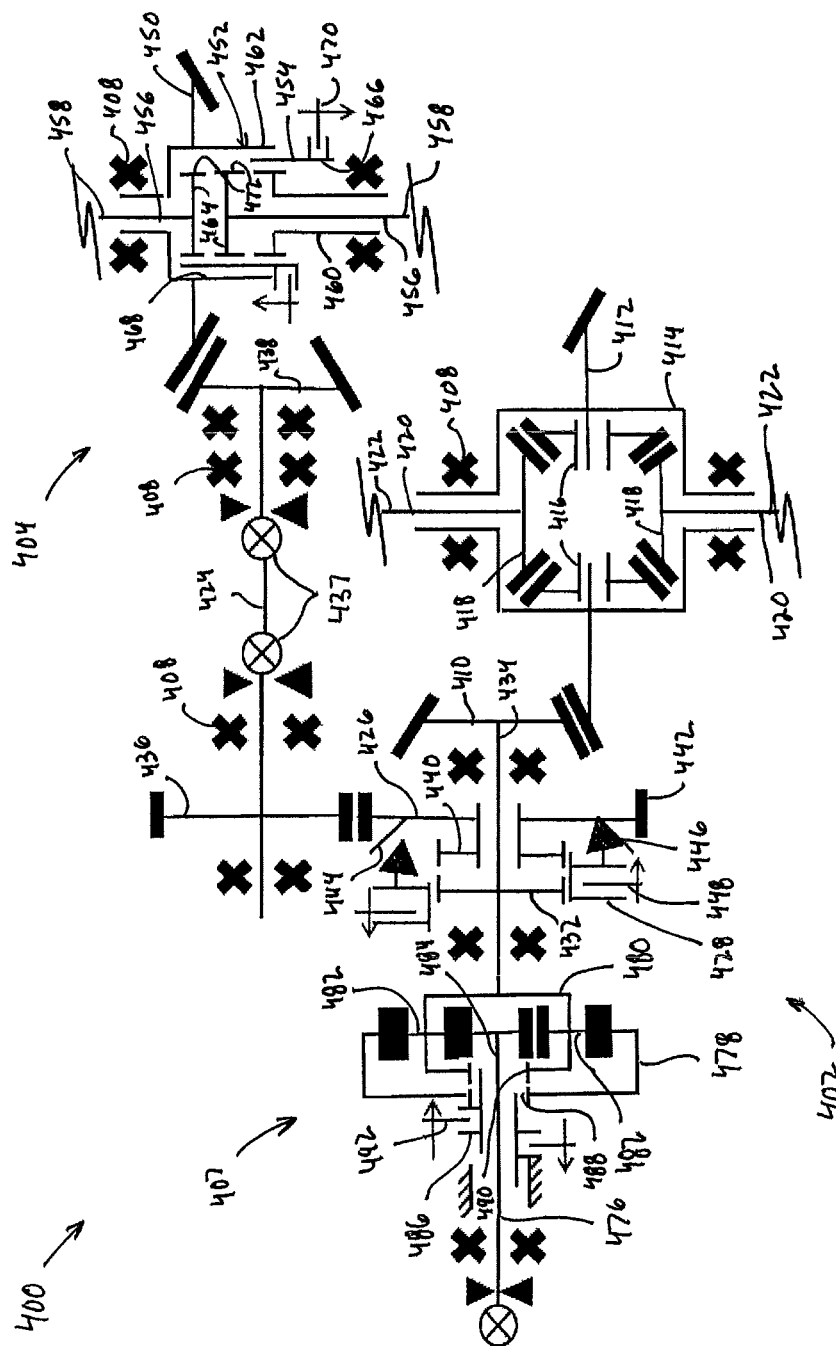


FIG. 3



**FIG. 4**

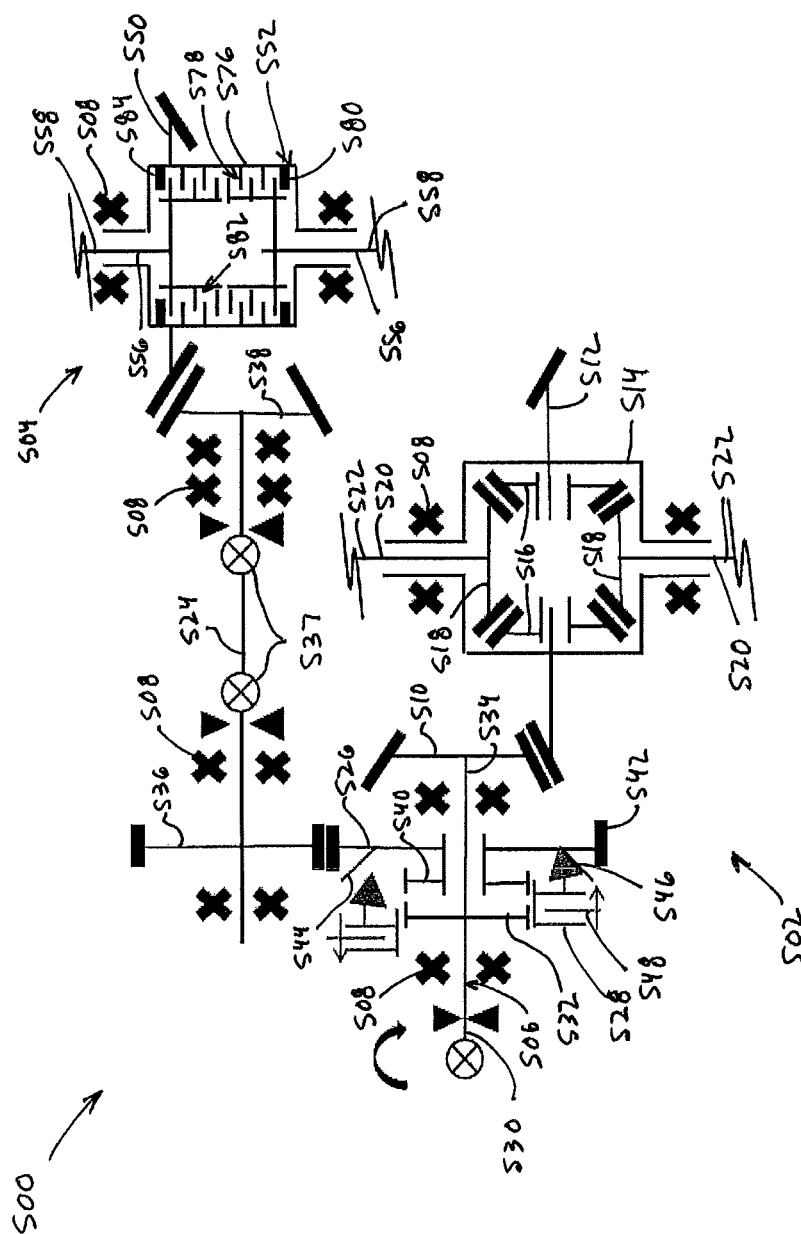
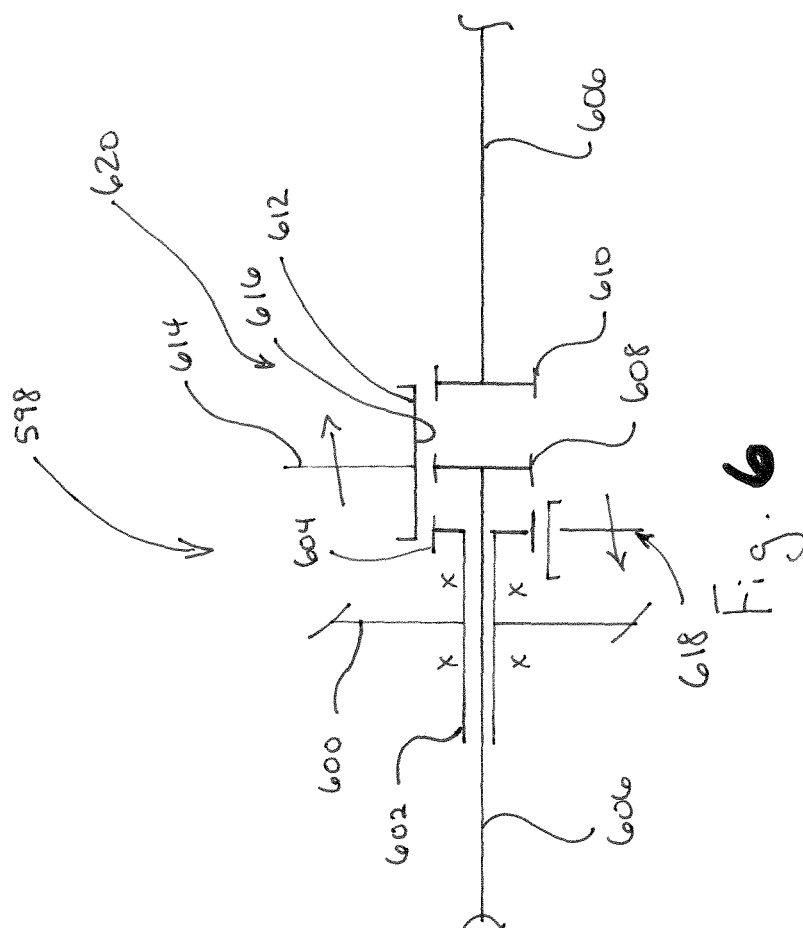


FIG. 5



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## TANDEM DRIVE AXLE SYSTEM WITH SIMPLIFIED REAR AXLE

### BACKGROUND TO THE EXEMPLARY EMBODIMENTS

Typical North American trucks have a full time 6×4 driveline. A 6×4 driveline typically means that there are 6 wheels on the truck and 4 of the wheels on two axles are driven. It is also typical that 6×4 drivelines have an interaxle differential and may or may not have optional wheel differential locks. The 6×4 system offers good traction in most conditions but suffers from spin losses and gear mesh inefficiencies.

6×2 systems (systems that have 6 wheels with 2 of them driving on a single axle) can improve spin losses and gear mesh inefficiencies but these systems are limited on tractive effort due to the single drive axle. The 6×2 system can utilize a wheel differential lock and an ability to shift weight to the drive axle under low traction conditions to improve tractive effort but it cannot equal the performance of the 6×4 system traction.

The 6×2 tandem is lighter than the 6×4 axle tandem but the suspension attachment for the non-drive tag axle is neither the same design nor the same roll stiffness as compared to the 6×4 tandem. What is needed is a tandem axle system that has the efficiency and lighter weight of the 6×2 system with the tractive effort and suspension interface of the 6×4 system.

### SUMMARY OF THE EXEMPLARY EMBODIMENTS

A tandem axle system has a forward rear tandem axle and a rear rear tandem axle. A rear differential case, a first axle half shaft and a second axle half shaft extending from the differential case. The first axle half shaft has a first set of teeth and the second axle half shaft has a second set of teeth. The rear differential case has a set of teeth. A clutch collar is provided which has teeth on a surface. The teeth selectively engage with the first axle half shaft teeth and the second axle half shaft teeth. The teeth selectively engage with the teeth on the rear differential case.

### SUMMARY OF THE FIGURES

The above, as well as other advantages of the present invention, will become readily apparent to those skilled in the art from the following detailed description when considered in the light of the accompanying drawings in which:

FIG. 1 is a schematic top view of a first embodiment of a tandem axle system;

FIG. 2 is a schematic top view of a second embodiment of a tandem axle system;

FIG. 3 is a schematic top view of a third embodiment of a tandem axle system;

FIG. 4 is a schematic top view of a fourth embodiment of a tandem axle system;

FIG. 5 is a schematic top view of a fifth embodiment of a tandem axle system; and

FIG. 6 is a schematic top view of one embodiment of a rear tandem axle system.

### DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

It is to be understood that the invention may assume various alternative orientations and step sequences, except where expressly specified to the contrary. It is also to be understood

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that the specific devices and processes illustrated in the attached drawings, and described in the following specification are simply exemplary embodiments of the inventive concepts defined herein. Hence, specific dimensions, directions or other physical characteristics relating to the embodiments disclosed are not to be considered as limiting, unless expressly stated otherwise.

FIG. 1 illustrates a tandem drive axle system **100** comprising a first axle assembly **102** and a second axle assembly **104**. An input source of rotational energy (not shown) is provided to turn a first pinion shaft **106** of the first axle assembly **102**. One or more bearings **108** may be located in contact with the first pinion shaft **106** to enable it to rotate within a first axle assembly housing (not shown). The first pinion shaft **106** has a first pinion gear **110** mounted thereto. The first pinion gear **110** has a toothed portion. The toothed portion is engaged with a toothed portion of a first axle driving gear **112**, also located within the first axle assembly housing. The first pinion gear **110** may be such as a hypoid pinion gear. The first pinion shaft **106** is drivingly engaged with the first axle driving gear **112** of the first axle assembly **102** through a single gear mesh.

The first axle driving gear **112** is mounted on, or connected, to a first wheel differential case **114**. At least two pinion gears **116** and at least two side gears **118** are located within the first wheel differential case **114**. As known by those skilled in the art, the pinion gears **116** and the side gears **118** are connected to one another. The side gears **118** are also connected to axle half shafts **120**. The axle half shafts **120** extend from the first wheel differential case **114** and the first axle assembly housing to a wheel end **122**. The wheel ends **122** supports wheels and tires (not shown).

The first axle assembly **102** includes the first pinion shaft **106**, a transfer shaft **124**, a second output gear **126**, and a shift collar **128**. Preferably, the components **106**, **124**, **126**, **128** are formed from a hardened steel, however the components **106**, **124**, **126**, **128** may be formed from any other rigid material. As shown, the first axle assembly **102** includes the four components **106**, **124**, **126**, **128** disposed in the first axle assembly housing but it is understood the first axle assembly **102** may include fewer or more components.

The first pinion shaft **106** is at least partially disposed in the first axle assembly housing. Preferably, the first pinion shaft **106** is an elongate cylindrical member; however the first pinion shaft **106** may be any other shape. The first pinion shaft **106** has a first end portion **130** drivingly engaged with the input source of rotational energy, a middle portion **132**, and a second end portion **134** drivingly engaged with the first pinion gear **110**.

The middle portion **132** is a radially extending flange having a set of clutch gear teeth formed thereon. The middle portion **132** is formed intermediate the first end portion **130** and the second end portion **134**. Preferably, the set of clutch gear teeth is unitary with the first pinion shaft **106**. However, it is understood that the set of clutch gear teeth may be formed in a collar that is splined to the first pinion shaft **106**.

The transfer shaft **124** comprises at least one elongate cylindrical member drivingly engaged with the second output gear **126** through a driven gear **136** coupled to the transfer shaft **124**. As illustrated, the transfer shaft **124** comprises a plurality of elongate cylindrical members connected by a pair of universal joints **137**. Bearings **108** disposed between the transfer shaft **124** and the first axle assembly housing and a second axle assembly housing (not shown) permit the transfer shaft **124** to rotate therein. The transfer shaft **124** extends from within the first axle assembly to within the second axle assembly housing.



A second pinion gear **138** is drivingly coupled to the transfer shaft **124** opposite the driven gear **136**. As is known in the art, the second pinion gear **138** has gear teeth formed on an outer surface thereof. The second pinion gear **138** may be one of a hypoid gear, a spiral bevel gear, a straight bevel gear, or any other gear known to those skilled in the art.

The second output gear **126** is a gear concentrically disposed about first pinion shaft **106**. The second output gear **126** has a central perforation having a diameter greater than a diameter of the first pinion shaft **106**. The second output gear **126** is a substantially disc shaped body having a first end portion **140**, a second end portion **142** defining an outer diameter of the second output gear **126**, and an engagement portion **144**. Bearings (not shown) disposed between the first pinion shaft **106** and the second output gear **126** permit the second output gear **126** to rotate about an axis of the second output gear **126**. The axis of the second output gear **126** is concurrent with the axis of the first pinion shaft **106**. A first set of clutch gear teeth are formed on the first end portion **140** adjacent the set of clutch gear teeth of the middle portion **132** of the first pinion shaft **106**. A second set of gear teeth are formed on the second end portion **142**.

The engagement portion **144** is formed in the second output gear **126** intermediate the first end portion **140** and the second end portion **142**. As shown, the engagement portion **144** is a conical surface oblique to the first pinion shaft **106**; however, the engagement portion **144** may have any other shape.

The shift collar **128** is concentrically disposed about the first pinion shaft **106**. The shift collar **128** includes a set of inner clutch collar teeth formed on an inner surface thereof and a first synchronizer ring **146**. The set of inner clutch collar teeth are engaged with the set of clutch gear teeth of the middle portion **132**. The shift collar **128** can be slidably moved along the axis of the first pinion shaft **106** as directed manually by an operator of the vehicle or automatically by an electronic control unit (not shown) while maintaining engagement of the inner clutch collar teeth and the set of clutch gear teeth of the middle portion. A shift fork **148** disposed in an annular recess formed in the shift collar **128** moves the shift collar **128** along the axis of the first pinion shaft **106** into a first position or a second position. A shift mechanism (not shown), which is drivingly engaged with the shift fork **148**, is actuated to position the shift fork **148** as directed manually by an operator of the vehicle or automatically by the electronic control unit. Consequently, the shift fork **148** positions the shift collar **128** into the first position or the second position. In the first position, the shift collar **128** is only drivingly engaged with the set of clutch gear teeth of the middle portion **132**. In the second position, the shift collar **128** is drivingly engaged with the set of clutch gear teeth of the middle portion **132** and the first set of clutch gear teeth of the first end portion **140** of the second output gear **126**. It is understood the shift collar **128**, the clutch gear teeth, the synchronizer ring **146**, and the engagement portion **144** may be substituted with any clutching device that permits selective engagement of a driving and a driven part.

The first synchronizer ring **146** is an annular body coupled to the shift collar **128** adjacent the engagement portion **144** of the second output gear **126**. The first synchronizer ring **146** has a first conical engagement surface. Alternately, the first synchronizer ring **146** may have an engagement surface having any other shape. A biasing member (not shown) is disposed between the shift collar **128** and the first synchronizer ring **146** to urge the first synchronizer ring **146** away from the shift collar **128**. When the shift collar **128** is moved from the first position into the second position, the first conical engage-

ment surface contacts the engagement portion **144** of the second output gear **126**. As the shift collar **128** moves towards the first set of clutch gear teeth of the first end portion **140** of the second output gear **126**, the biasing member is compressed while the shift collar **128** engages the set of clutch gear teeth of the middle portion **132** and before the shift collar **128** engages the first set of clutch gear teeth of the first end portion **140** of the second output gear **126**.

The second axle assembly **104** includes a second axle driving gear **150**, a second wheel differential case **152**, a second shift collar **154**, and a pair of second axle half shafts **156**. Preferably, the components **150**, **152**, **154**, **156** are formed from a hardened steel, however the components **150**, **152**, **154**, **156** may be formed from any other rigid material. As shown, the second axle assembly **104** includes the four components **150**, **152**, **154**, **156** disposed in the second axle assembly housing but it is understood the second axle assembly **104** may include fewer or more components.

The second axle driving gear **150** is mounted on, or connected, to the second wheel differential case **152**. The second wheel differential case **152** may be drivingly engaged with the second axle half shafts **156** by engaging the second shift collar **154** with the second wheel differential case **152** and each of the second axle half shafts **156**. The second axle half shafts **156** extend from the second wheel differential case **152** and the second axle assembly housing to a wheel end **158**. The wheel ends **158** supports wheels and tires (not shown).

The second wheel differential case **152** comprises an inner portion **160** and an outer portion **162**. The inner portion **160** is partially disposed within the outer portion **162**. The inner portion **160** is drivingly engaged with the outer portion **162**. The second shift collar **154** is disposed through at least one perforation formed in the second wheel differential case **152**.

The inner portion **160** is a hollow annular member rotatably mounted with the second axle assembly housing at least one bearing **108**. One of the second axle half shafts **156** is rotatably disposed through the inner portion **160**. An end portion **164** includes a plurality of clutch teeth formed on an outer surface thereof for engaging corresponding clutch teeth formed on an inner surface **166** of the second shift collar **154**.

The outer portion **162** is a hollow annular member rotatably mounted with the second axle assembly housing at least one bearing **108**. One of the second axle half shafts **156** is rotatably disposed through the outer portion **160**. An inner surface **168** of the second wheel differential housing **152** includes a plurality of clutch teeth formed thereon for engaging corresponding clutch teeth formed on an outer surface of the second shift collar **154**. The second shift collar **154** is in sliding driving engagement with the inner surface **168** of the second wheel differential housing **152**.

A second shift fork **170** disposed in an annular recess formed in the second shift collar **154** moves the second shift collar **154** along the axis of the second axle half shafts **156** into a first position or a second position. A shift mechanism (not shown), which is drivingly engaged with the second shift fork **170**, is actuated to position the second shift fork **170** as directed manually by an operator of the vehicle or automatically by the electronic control unit. The second shift collar **154** can be slidably moved along the axis of the second axle half shafts **156** as directed manually by an operator of the vehicle or automatically by an electronic control unit (not shown) while maintaining engagement with the plurality of clutch teeth formed in the inner surface **168** while being engaged with the plurality of clutch teeth formed on a toothed outer surface **172** of the end portion **164**. Consequently, the second shift fork **170** positions the second shift collar **154** into the first position or the second position. In the first position,

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the second shift collar **154** is only drivingly engaged with the inner surface **168**. In the second position, the second shift collar **154** is drivingly engaged with the inner surface **168** and the toothed outer surface **172** of each of the second axle half shafts **156**. When the second shift collar **154** is placed in the second position, each of the second axle half shafts **156** is drivingly engaged with the second axle driving gear **150**. It is understood the second shift collar **154**, the inner surface **168**, and the second axle half shafts **156** may be substituted with any clutching device that permits selective engagement of a driving and a driven part.

FIG. 2 illustrates a tandem drive axle system **200** according to another embodiment of the invention. The tandem drive axle system **200** comprises a first axle assembly **202** and a second axle assembly **204**. An input source of rotational energy (not shown) is provided to turn a first pinion shaft **206** of the first axle assembly **202**. One or more bearings **208** may be located in contact with the first pinion shaft **206** to enable it to rotate within a first axle assembly housing (not shown). The first pinion shaft **206** has a first pinion gear **210** mounted thereto. The first pinion gear **210** has a toothed portion. The toothed portion is engaged with the forward side of a toothed portion of a first axle driving gear **212**, also located within the first axle assembly housing. The first pinion gear **210** may be such as a hypoid pinion gear. The first pinion shaft **206** is drivingly engaged with the first axle driving gear **212** of the first axle assembly **202** through a single gear mesh.

The first axle assembly **202** includes the first pinion shaft **206**, the first axle driving gear **212**, a first wheel differential case **214**, a second pinion shaft **216**, a first shift collar **218**, and an output shaft **220**. Preferably, the components **206**, **212**, **214**, **216**, **218**, and **220** are formed from a hardened steel, however the components **206**, **212**, **214**, **216**, **218**, and **220** may be formed from any other rigid material. As shown, the first axle assembly **202** includes the six components **206**, **212**, **214**, **216**, **218**, and **220** disposed in the first axle assembly housing but it is understood the first axle assembly **202** may include fewer or more components.

The first axle driving gear **212** is mounted on, or connected, to a first wheel differential case **214**. At least two pinion gears **222** and at least two side gears **224** are located within the first wheel differential case **214**. As known by those skilled in the art, the pinion gears **222** and the side gears **224** are connected to one another. The side gears **224** are also connected to axle half shafts **226**. The axle half shafts **226** extend from the first wheel differential case **214** and the first axle assembly housing to a wheel end **228**. The wheel ends **228** supports wheels and tires (not shown).

The second pinion shaft **216** is drivingly engaged with a rearward side of the toothed portion of the first axle driving gear **212**. A second pinion gear **230** is mounted to the second pinion shaft **216**. The second pinion shaft **216** is mounted using at least one bearing **208** to facilitate rotation of the second pinion shaft **216** within the first axle assembly housing. The second pinion gear **230** may be a hypoid pinion gear. The second pinion shaft **226** further comprises a toothed end portion **232** opposite the second pinion gear **230**. The toothed end portion **232** is drivingly engaged with the first shift collar **218**.

The output shaft **220** is an annular member at least partially disposed within the first axle assembly housing. The output shaft **220** has a first end portion **234**, a second end portion **236**, and an engagement portion **238**. Bearings **208** disposed between the output shaft **220** and the first axle assembly housing permit the output shaft **220** to rotate about an axis of the output shaft **220**. The axis of the output shaft **220** is concurrent with the axis of the second pinion shaft **216**. A set

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of clutch gear teeth are formed on the first end portion **234** adjacent the toothed end portion **232** of the second pinion shaft **216**. The second end portion **236** is drivingly engaged with an inter-axle shaft **240**.

The engagement portion **238** is a radially extending portion of the output shaft **220** formed intermediate the first end portion **234** and the second end portion **236**. As shown, the engagement portion **238** is a conical surface oblique to the output shaft **220**; however, the engagement portion **238** may have any other shape.

The first shift collar **218** is concentrically disposed about the second pinion shaft **216**. The first shift collar **218** includes a set of inner clutch collar teeth formed on an inner surface thereof and a synchronizer ring **242**. The set of inner clutch collar teeth are engaged with the toothed end portion **232** of the second pinion shaft **216**. The first shift collar **218** can be slidably moved along the axis of the second pinion shaft **216** as directed manually by an operator of the vehicle or automatically by an electronic control unit (not shown) while maintaining engagement of the inner clutch collar teeth and the toothed end portion **232** of the second pinion shaft **216**. A shift fork **244** disposed in an annular recess formed in the first shift collar **218** moves the first shift collar **218** along the axis of the second pinion shaft **216** into a first position or a second position. A shift mechanism (not shown), which is drivingly engaged with the shift fork **244**, is actuated to position the shift fork **244** as directed manually by an operator of the vehicle or automatically by the electronic control unit. Consequently, the shift fork **244** positions the first shift collar **218** into the first position or the second position. In the first position, the first shift collar **218** is only drivingly engaged with the toothed end portion **232** of the second pinion shaft **216**. In the second position, the first shift collar **218** is drivingly engaged with the toothed end portion **232** of the second pinion shaft **216** and the first end portion **234** of the output shaft **220**. It is understood the first shift collar **218**, the toothed end portion **232**, and the output shaft **220** may be substituted with any clutching device that permits selective engagement of a driving and a driven part.

The synchronizer ring **242** is an annular body coupled to the shift collar **218** adjacent the engagement portion **238** of the output shaft **220**. The synchronizer ring **242** has a first conical engagement surface. Alternately, the synchronizer ring **242** may have an engagement surface having any other shape. A biasing member (not shown) is disposed between the shift collar **218** and the synchronizer ring **242** to urge the synchronizer ring **242** away from the shift collar **218**. When the shift collar **218** is moved from the first position into the second position, the first conical engagement surface contacts the engagement portion **238** of the output shaft **220**. As the shift collar **218** moves towards the set of clutch gear teeth formed on the first end portion **234** of the output shaft **220**, the biasing member is compressed while the shift collar **218** engages the toothed end portion **232** of the second pinion shaft **216** and before the shift collar **218** engages the set of clutch gear teeth formed on the first end portion **234** of the output shaft **220**.

The inter-axle shaft **240** comprises at least one elongate cylindrical member drivingly engaged with the output shaft **220** and a third pinion shaft **246**. As illustrated, the inter-axle shaft **240** comprises an elongate cylindrical member having universal joints **247** disposed on each end. The inter-axle shaft **240** extends from adjacent the first axle assembly to adjacent the second axle assembly housing.

The second axle assembly **204** includes the third pinion shaft **246**, a second axle driving gear **250**, a second wheel differential case **252**, a second shift collar **254**, and a pair of

second axle half shafts **256**. Preferably, the components **246**, **250**, **252**, **254**, **256** are formed from a hardened steel, however the components **246**, **250**, **252**, **254**, **256** may be formed from any other rigid material. As shown, the second axle assembly **204** includes the five components **246**, **250**, **252**, **254**, **256** disposed in the second axle assembly housing but it is understood the second axle assembly **204** may include fewer or more components.

The third pinion shaft **246** is drivingly engaged with the inter-axle shaft **240** and the second axle driving gear **250**. A third pinion gear **257** is mounted to the third pinion shaft **246**. The third pinion shaft **246** is mounted using at least one bearing **208** to facilitate rotation of the third pinion shaft **246** within the second axle assembly housing. The third pinion gear **257** may be a hypoid pinion gear.

The second axle driving gear **250** is mounted on, or connected, to the second wheel differential case **252**. The second wheel differential case **252** may be drivingly engaged with the second axle half shafts **256** by engaging the second shift collar **254** with the second wheel differential case **252** and each of the second axle half shafts **256**. The second axle half shafts **256** extend from the second wheel differential case **252** and the second axle assembly housing to a wheel end **258**. The wheel ends **258** supports wheels and tires (not shown).

The second wheel differential case **252** comprises an inner portion **260** and an outer portion **262**. The inner portion **260** is partially disposed within the outer portion **262**. The inner portion **260** is drivingly engaged with the outer portion **262**. The second shift collar **254** is disposed through at least one perforation formed in the second wheel differential case **252**.

The inner portion **260** is a hollow annular member rotatably mounted with the second axle assembly housing at least one bearing **208**. One of the second axle half shafts **256** is rotatably disposed through the inner portion **260**. An end portion **264** includes a plurality of clutch teeth formed on an outer surface thereof for engaging corresponding clutch teeth formed on an inner surface **266** of the second shift collar **254**.

The outer portion **262** is a hollow annular member rotatably mounted with the second axle assembly housing at least one bearing **208**. One of the second axle half shafts **256** is rotatably disposed through the outer portion **260**. An inner surface **268** of the outer portion **262** includes a plurality of clutch teeth formed thereon for engaging corresponding clutch teeth formed on an outer surface of the second shift collar **254**. The second shift collar **254** is in sliding driving engagement with the inner surface **268** of the second wheel differential case **252**.

A second shift fork **270** disposed in an annular recess formed in the second shift collar **254** moves the second shift collar **254** along the axis of the second axle half shafts **256** into a first position or a second position. A shift mechanism (not shown), which is drivingly engaged with the second shift fork **270**, is actuated to position the second shift fork **270** as directed manually by an operator of the vehicle or automatically by the electronic control unit. The second shift collar **254** can be slidably moved along the axis of the second axle half shafts **256** as directed manually by an operator of the vehicle or automatically by an electronic control unit (not shown) while maintaining engagement with the plurality of clutch teeth formed on the inner surface **268** while being engaged with the plurality of clutch teeth formed on a toothed outer surface **272** of the end portion **264**. Consequently, the second shift fork **270** positions the second shift collar **254** into the first position or the second position. In the first position, the second shift collar **254** is only drivingly engaged with the inner surface **268**. In the second position, the second shift collar **254** is drivingly engaged with the inner surface **268**,

and the toothed outer surface **272** of each of the second axle half shafts **256**. When the second shift collar **254** is placed in the second position, each of the second axle half shafts **256** is drivingly engaged with the second axle driving gear **250**. It is understood the second shift collar **254**, the inner surface **268**, and the second axle half shafts **256** may be substituted with any clutching device that permits selective engagement of a driving and a driven part.

FIG. 3 illustrates a tandem drive axle system **300** according to another embodiment of the invention. The embodiment shown in FIG. 3 includes similar components to the tandem drive axle system **100** illustrated in FIG. 1. Similar features of the embodiment shown in FIG. 3 are numbered similarly in series, with the exception of the features described below.

The tandem drive axle system **300** further comprises a planetary drive ratio adjuster **305**. The planetary drive ratio adjuster **305** is in driving engagement with a planetary input shaft **376** and the first pinion shaft **306**. An input source of rotational energy (not shown) is provided to turn the planetary input shaft **376**. When placed in an engaged position, the planetary drive ratio adjuster **305** adjusts a drive ratio between the planetary input shaft **376** and the first pinion shaft **306**.

The planetary drive ratio adjuster **305** comprises a ring gear member **378**, a carrier member **380**, a plurality of planet gears **382**, a sun gear member **384**, and an engagement collar **386**. The planetary drive ratio adjuster **305** forms an epicyclic gearset.

The ring gear member **378** is an annular member drivingly engaged with the planetary input shaft **376** and each of the plurality of planet gears **382**. It is understood that the ring gear member **378** may comprise a plurality of members coupled together or that the ring gear member **378** may be unitarily formed with the planetary input shaft **376**. The ring gear member **378** comprises a plurality of gear teeth formed on an inner surface thereof that form a ring gear. The ring gear is drivingly engaged with each of the plurality of planet gears **382**.

The carrier member **380** is an annular member drivingly engaged with the first pinion shaft **306** and having each of the plurality of planet gears **382** rotatably disposed thereon in an annular array. It is understood that the carrier member **380** may comprise a plurality of members coupled together or that the carrier member **380** may be unitarily formed with the first pinion shaft **306**. The carrier member **380** includes a toothed engagement portion **388**, disposed adjacent the engagement collar **386**, which may be drivingly engaged therewith.

The plurality of planet gears **382** are gears rotatably disposed on the carrier member **380**. Each of the planet gears **382** is drivingly engaged with the ring gear member **380** and the sun gear member **384**. When the planetary drive ratio adjuster **305** is placed in the engaged position, each of the planet gears **382** are driven about the sun gear member **384**, which drives the carrier member **380**.

The sun gear member **384** is an annular member rotatably disposed about the first pinion shaft **306** and drivingly engaged with each of the plurality of planet gears **382**. It is understood that the sun gear member **384** may comprise a plurality of members coupled together or that the sun gear member **384** may be unitarily formed with the first pinion shaft **306**. The sun gear member **384** comprises a plurality of gear teeth formed on an outer surface thereof that form a sun gear. The sun gear is drivingly engaged with each of the plurality of planet gears **382**. The sun gear member **384** includes a toothed engagement portion **390**, disposed adjacent the engagement collar **386**, which is drivingly engaged therewith.

The engagement collar **386** is concentrically disposed about a portion of the first pinion shaft **306**. The engagement collar **386** includes a set of inner collar teeth formed on an inner surface thereof. The set of inner collar teeth may be engaged with a plurality of grounding teeth formed on a portion of a first axle assembly housing (not shown) or a member coupled thereto. The engagement collar **386** may be slidably moved along the axis of the first pinion shaft **306** as directed manually by an operator of the vehicle or automatically by an electronic control unit (not shown) while maintaining engagement with the plurality of grounding teeth formed on a portion of a first axle assembly housing and the toothed engagement portion **390** of the sun gear member **384**. An adjuster shift fork **392** disposed in an annular recess formed in the engagement collar **386** moves the engagement collar **386** along the axis of the first pinion shaft **306** into the engaged position or the disengaged position. A shift mechanism (not shown), which is drivingly engaged with the adjuster shift fork **392**, is actuated to position the adjuster shift fork **392** as directed manually by an operator of the vehicle or automatically by the electronic control unit. Consequently, the adjuster shift fork **392** positions the engagement collar **386** into the engaged position or the disengaged position. In the engaged position, the engagement collar **386** is drivingly engaged with plurality of grounding teeth formed on a portion of a first axle assembly housing and the toothed engagement portion **390** of the sun gear member **384**, which fixes the sun gear member **384** and causes the carrier member **380** to be driven by the plurality of planet gears **382** in response to the ring gear member **378** being driven, resulting in the planetary input shaft **376** and the first pinion shaft **306** to be in a relative torque multiplication ratio. As a non-limiting example, the relative torque multiplication ratio may be 1.36:1; however, it is understood that other ratios may be used. In the disengaged position, the engagement collar **386** is drivingly engaged with the toothed engagement portion **390** of the sun gear member **384** and the toothed engagement portion **388** of the carrier member **380**, which fixes the sun gear member **384** with respect to the carrier member **380** and causes the planetary drive ratio adjuster **305** to be placed in a "locked out" condition, resulting in the planetary input shaft **376** and the first pinion shaft **306** to be driven in a 1:1 drive ratio.

FIG. 4 illustrates a portion of a tandem drive axle system **400** according to another embodiment of the invention. The embodiment shown in FIG. 4 includes similar components to the tandem drive axle system **100** illustrated in FIG. 1. Similar features of the embodiment shown in FIG. 4 are numbered similarly in series, with the exception of the features described below.

The tandem drive axle system **400** further comprises a planetary drive ratio adjuster **407**. The planetary drive ratio adjuster **407** is in driving engagement with a planetary input shaft **476** and the first pinion shaft **406**. An input source of rotational energy (not shown) is provided to turn the planetary input shaft **476**. When placed in an engaged position, the planetary drive ratio adjuster **407** adjusts a drive ratio between the planetary input shaft **476** and the first pinion shaft **406**.

The planetary drive ratio adjuster **407** comprises a ring gear member **478**, a carrier member **480**, a plurality of planet gears **482**, a sun gear member **484**, and an engagement collar **486**. The planetary drive ratio adjuster **407** forms an epicyclic gearset.

The ring gear member **478** is an annular member rotatably disposed about the planetary input shaft **476** and drivingly engaged with each of the plurality of planet gears **482**. It is understood that the ring gear member **478** may comprise a

plurality of members coupled together or that the ring gear member **478** may be unitarily formed. The ring gear member **478** comprises a plurality of gear teeth formed on an inner surface thereof that form a ring gear. The ring gear is drivingly engaged with each of the plurality of planet gears **482**. The ring gear member **478** includes a toothed engagement portion **488**, disposed adjacent the engagement collar **486**, which is drivingly engaged therewith.

The carrier member **480** is an annular member drivingly engaged with the first pinion shaft **406** and having each of the plurality of planet gears **482** rotatably disposed thereon in an annular array. It is understood that the carrier member **480** may comprise a plurality of members coupled together or that the carrier member **480** may be unitarily formed with the first pinion shaft **406**. The carrier member **480** includes a toothed engagement portion **490**, disposed adjacent the engagement collar **486**, which may be drivingly engaged therewith.

The plurality of planet gears **482** are gears rotatably disposed on the carrier member **480**. Each of the planet gears **482** is drivingly engaged with the ring gear member **480** and the sun gear member **484**. When the planetary drive ratio adjuster **407** is placed in the engaged position, each of the planet gears **482** are driven by the sun gear member **484** about the ring gear member **478**, which drives the carrier member **480**.

The sun gear member **484** is an annular member drivingly engaged with the planetary input shaft **476** and each of the plurality of planet gears **482**. It is understood that the sun gear member **484** may comprise a plurality of members coupled together or that the sun gear member **484** may be unitarily formed with the planetary input shaft **476**. The sun gear member **484** comprises a plurality of gear teeth formed on an outer surface thereof that form a sun gear. The sun gear is drivingly engaged with each of the plurality of planet gears **482**.

The engagement collar **486** is concentrically disposed about a portion of the planetary input shaft **476**. The engagement collar **486** includes a set of outer collar teeth formed on an outer surface thereof. The set of outer collar teeth may be engaged with a plurality of grounding teeth formed on a portion of a first axle assembly housing (not shown) or a member coupled thereto. The engagement collar **486** may be slidably moved along the axis of the planetary input shaft **476** as directed manually by an operator of the vehicle or automatically by an electronic control unit (not shown) while maintaining engagement with the plurality of grounding teeth formed on a portion of a first axle assembly housing and the toothed engagement portion **488** of the ring gear member **478**. An adjuster shift fork **492** disposed in an annular recess formed in the engagement collar **486** moves the engagement collar **486** along the axis of the planetary input shaft **476** into the engaged position or the disengaged position. A shift mechanism (not shown), which is drivingly engaged with the adjuster shift fork **492**, is actuated to position the adjuster shift fork **492** as directed manually by an operator of the vehicle or automatically by the electronic control unit. Consequently, the adjuster shift fork **492** positions the engagement collar **486** into the engaged position or the disengaged position. In the engaged position, the engagement collar **486** is drivingly engaged with plurality of grounding teeth formed on a portion of a first axle assembly housing and the toothed engagement portion **488** of the ring gear member **478**, which fixes the ring gear member **478** and causes the carrier member **480** to be driven by the plurality of planet gears **482** in response to the sun gear member **484** being driven, resulting in the planetary input shaft **476** and the first pinion shaft **434** to be in a relative torque multiplication ratio. As a non-limiting example, the relative torque multiplication ratio may be

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4:1; however, it is understood that other ratios may be used. In the disengaged position, the engagement collar **486** is driv-  
ingly engaged with the toothed engagement portion **488** of the  
ring gear member **478** and the toothed engagement portion  
**490** of the carrier member **480**, which fixes the ring gear  
member **478** with respect to the carrier member **480** and  
causes the planetary drive ratio adjuster **407** to be placed in a  
“locked out” condition, resulting in the planetary input shaft  
**476** and the first pinion shaft **406** to be driven in a 1:1 drive  
ratio.

FIG. 5 illustrates a portion of a tandem drive axle system  
**500** according to another embodiment of the invention. The  
embodiment shown in FIG. 5 includes similar components to  
the tandem drive axle system **100** illustrated in FIG. 1. Similar  
features of the embodiment shown in FIG. 5 are numbered  
similarly in series, with the exception of the features  
described below.

The tandem drive axle system **500** further comprises a plate  
clutch differential assembly **552**, which is in driving engage-  
ment with the second axle driving gear **550**. The plate clutch  
differential assembly **552** comprises a housing **576**, a first set  
of intermeshed plates **578**, a first actuator **580**, a second set of  
intermeshed plates **582**, and a second actuator **584**. The first  
set of intermeshed plates **578**, the first actuator **580**, the sec-  
ond set of intermeshed plates **582**, and the second actuator  
**584** are disposed within the housing **576** and facilitate driving  
engagement between the housing **576** and the second axle  
half shafts **556**.

The housing **576** is a hollow, annular member disposed  
within the second axle assembly housing (not shown) and  
rotatably supported using at least a pair of bearings **508**. The  
housing **576** comprises a plurality of members coupled  
together in any conventional manner. The housing **576** has a  
splined inner surface which at least a portion of the inter-  
meshed plates **578**, **582** are drivingly engaged with.

The first set of intermeshed plates **578** comprises a first  
plurality of plates drivingly engaged with the housing **576**  
intermeshed with a second plurality of plates drivingly  
engaged with a splined outer surface of one of the second axle  
half shafts **556**.

The first actuator **580** is an annular actuator disposed  
within the housing **576**. When engaged by a controller (not  
shown), the first actuator **580** applies a force to the first set of  
intermeshed plates **578**, causing driving engagement to occur  
between the housing **576** and one of the second axle half  
shafts **556**. The first actuator **580** may be hydraulically, pneu-  
matically, electronically, or mechanically actuated by the  
controller.

The second set of intermeshed plates **582** comprises a first  
plurality of plates drivingly engaged with the housing **576**  
intermeshed with a second plurality of plates drivingly  
engaged with a splined outer surface of a remaining one of the  
second axle half shafts **556**.

The second actuator **584** is an annular actuator disposed  
within the housing **576**. When engaged by the controller, the  
second actuator **584** applies a force to the second set of  
intermeshed plates **582**, causing driving engagement to occur  
between the housing **576** and the remaining one of the second  
axle half shafts **556**. The second actuator **584** may be hydrau-  
lically, pneumatically, electronically, or mechanically actu-  
ated by the controller. Further, it is understood that the plate  
clutch differential assembly **552** may comprise a single set of  
clutch plates and a single actuator or that the first actuator **580**  
and the second actuator **584** may be actuated independently  
of one another to facilitate a differential function.

In use, the tandem axle drive system **100**, **200**, **300**, **400**,  
**500** facilitates use of the first axle assembly **102**, **202**, **302**,

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**402**, **502** for a full time drive duty cycle and the second axle  
assembly **104**, **204**, **304**, **404**, **504** may be sized for intermit-  
tent use under low traction conditions. When a vehicle (not  
shown) the tandem axle drive system **100**, **200**, **300**, **400**, **500**  
is incorporated in is not operating in the low traction condi-  
tions, and the second axle assembly **104**, **204**, **304**, **404**, **504**  
is drivingly disengaged from the first axle assembly **102**, **202**,  
**302**, **402**, **502** and allowed to idle. The components of the  
second axle assembly **104**, **204**, **304**, **404**, **504** can be sized  
based on to a limited duty cycle of the second axle assembly  
**104**, **204**, **304**, **404**, **504**, which reduces a cost and a weight of  
the tandem axle drive system **100**, **200**, **300**, **400**, **500**.

The tandem axle drive system **100**, **200**, **300**, **400**, **500**  
allows an inter-axle differential and an axle wheel differen-  
tial, which are common among tandem axle drive systems, to  
be eliminated, which further reduces the cost and the weight  
of the tandem axle drive system **100**, **200**, **300**, **400**, **500**. The  
inter-axle differential and the axle wheel differential may be  
eliminated because the second axle assembly **104**, **204**, **304**,  
**404**, **504** is only engaged when the low traction conditions are  
present. The use of the shift collars **128**, **154**, **218**, **254**, **328**,  
**354**, **428**, **454**, **528** and the plate clutch differential assembly  
**552** allow for the second axle assembly **104**, **204**, **304**, **404**,  
**504** to be simply drivingly engaged or drivingly disengaged  
from the first axle assembly **102**, **202**, **302**, **402**, **502**. The  
second shift collar **154**, **254**, **354**, **454** is used to drivingly  
engage the second axle half shafts **156**, **256**, **356**, **456** with the  
second axle driving gear **150**, **250**, **350**, **450** when the second  
shift collar **154**, **254**, **354**, **454** is placed into an engaged  
position. The second shift collar **154**, **254**, **354**, **454** disen-  
gages the second axle half shafts **156**, **256**, **356**, **456** from the  
second axle driving gear **150**, **250**, **350**, **450** when the second  
shift collar **154**, **254**, **354**, **454** is placed into an disengaged  
position, allowing the second axle assembly **104**, **204**, **304**,  
**404** to be placed in an idle mode without the need for a  
differential lock function, as the second axle assembly **104**,  
**204**, **304**, **404** does not include a differential.

Further, it is understood that the tandem axle drive system  
**100**, **200**, **300**, **400**, **500** may incorporate synchronizers to  
facilitate engagement of the second axle assembly **104**, **204**,  
**304**, **404**, **504**. A single synchronizer or an overrunning clutch  
may be used to engage the second axle assembly **104**, **204**,  
**304**, **404**, **504** with the first axle assembly **102**, **202**, **302**, **402**,  
**502** without the need for an inter-axle differential lock func-  
tion, as an inter-axle differential is not used.

It is also understood that the second axle assembly **104**,  
**204**, **304**, **404**, **504** may be drivingly engaged without inter-  
action from the operator of the vehicle or without interfering  
with operation of the vehicle in response to a detected wheel  
slip of one of the wheels drivingly engaged with the first axle  
assembly **102**, **202**, **302**, **402**, **502**.

The first axle assembly **102** of the tandem drive axle system  
**100** includes a helical gear drive paired with one of a syn-  
chronizer and an overrunning clutch to facilitate driving  
engagement with the second axle assembly **104**. When the  
second axle assembly **104** is in an idle mode, the shift collar  
**128** is partially engaged to “spool up” the second axle assem-  
bly **104** before drivingly engaging the second axle assembly  
**104** with the first axle assembly **102**.

The first axle assembly **202** of the tandem drive axle system  
**200** eliminates the helical gearing and instead employs the  
second pinion shaft **216** in driving engagement with the first  
axle driving gear **212** as a power takeoff. When the second  
axle assembly **204** is in an idle mode, the shift collar **218** is  
partially engaged to “spool up” the second axle assembly **204**  
before drivingly engaging the second axle assembly **204** with  
the first axle assembly **202**.

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The first axle assembly **302** of the tandem drive axle system **300** includes the planetary drive ratio adjuster **305**, which reduces a rotational speed of the first pinion shaft **306** when engaged to increase an amount of torque applied thereto. The planetary drive ratio adjuster **305** may be engaged automatically or manually, regardless of an engagement status of the second axle assembly **304**.

The first axle assembly **502** of the tandem drive axle system **500** includes the plate clutch differential assembly **552**. The plate clutch differential assembly **552** can be used to provide a torque vectoring function and/or to limit an amount of torque applied to the second axle shafts **556**.

Turning now to FIG. 6, another embodiment of a second axle assembly **598** is depicted. A second axle driving gear **600** is depicted connected to a differential case **602**. The differential case **602** has a first set of teeth **604**. The second axle assembly **598** also has two second axle half shafts **606** extending into the differential case **602**. Each inboard end of each second axle half shaft has a set of teeth **608**, **610** thereon.

A second shift collar **612** is provided with a set of inner teeth **616** thereon. The second shift collar **612** is selectively moved between teeth **604**, **608** and **610** by a shift fork **614**. In a first position **618**, the inner teeth **616** are engaged only with teeth **604**. In the first position, the second axle half shafts **606** are not drivingly connected to the shift collar **612**, and they are free rotate with respect to one another and the shift collar **612**. In a second position **620**, the second shift collar **612** slides into engagement with teeth **604**, **608** and **610** to lock them into common rotation.

In accordance with the provisions of the patent statutes, the present invention has been described in what is considered to represent its preferred embodiments. However, it should be noted that the invention can be practiced otherwise than as specifically illustrated and described without departing from its spirit or scope.

The invention claimed is:

1. A tandem axle system, comprising:

a forward rear tandem axle;

a rear rear tandem axle;

a transfer shaft located between said forward rear tandem axle and said rear rear tandem axle;

a mechanism for selectively engaging and disengaging said transfer shaft;

a rear case having an inner portion and an outer portion, a first axle half shaft and a second axle half shaft extending from said rear case wherein said first axle half shaft has a first set of teeth located within said inner portion of said rear case and said second axle half shaft has a second set of teeth located within said inner portion of said rear case, wherein said inner portion of said rear case has a set of teeth; and

a single clutch collar slidable within said inner portion of said rear case, said clutch collar having inner teeth on an inner surface of said collar and outer teeth on an outer surface of said clutch collar wherein said inner teeth selectively engage with said first axle half shaft teeth and said second axle half shaft teeth and said outer teeth selectively engage with first set of teeth on said rear case; wherein said rear case does not have a differential.

2. The tandem axle system of claim 1, wherein said clutch collar has

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a first position where said collar is only engaged with the inner portion of the rear case.

3. The tandem axle system of claim 1, wherein said clutch collar has a second position where said collar is engaged with the inner portion of the rear case and each of said axle half shafts.

4. The tandem axle system of claim 3, wherein in the second position the axle half shafts are engaged with a ring gear connected to said rear case.

5. The tandem axle system of claim 1, wherein said forward rear tandem axle has a first pinion shaft with a middle portion bearing a toothed radially extending flange, wherein an output gear and a forward shift collar are concentrically disposed about said first pinion shaft, wherein said forward shift collar selectively engages said toothed radially extending flange and said output gear.

6. The tandem axle system of claim 1, wherein said forward rear tandem axle comprises a first pinion shaft driving a first pinion which drives a ring gear connected to both a forward differential and a second pinion.

7. The tandem axle system of claim 6, wherein said second pinion is connected to a second pinion shaft, wherein a shift collar selectively engages a toothed end of said second pinion shaft and a set of clutch gear teeth on an output shaft sharing the same axis as the second pinion shaft.

8. The tandem axle system of claim 1, wherein said forward rear tandem axle is comprised of a planetary drive ratio adjuster for adjusting a drive ratio between a planetary input shaft and a first pinion shaft, said planetary drive ratio adjuster comprising planet gears, a ring gear member, a carrier member, a sun gear member and an engagement collar.

9. The tandem axle system of claim 8, wherein in a first position said engagement collar fixed said sun gear member and causes the carrier member to be driven by the planet gears resulting in the planetary input shaft and the first pinion shaft to be in a relative torque multiplication ratio.

10. The tandem axle system of claim 9, wherein said forward rear tandem axle has a first pinion shaft with a middle portion bearing a toothed radially extending flange, wherein an output gear and a forward shift collar are concentrically disposed about said first pinion shaft, wherein said forward shift collar selectively engages said toothed radially extending flange and said output gear.

11. A tandem axle system, comprising:

a forward rear tandem axle;

a rear rear tandem axle;

a transfer shaft located between said forward rear tandem axle and said rear rear tandem axle;

a mechanism for selectively engaging and disengaging said transfer shaft;

a rear case, a first axle half shaft and a second axle half shaft extending from said rear case wherein said first axle half shaft has a first set of teeth and said second axle half shaft has a second set of teeth, wherein rear case has a third set of teeth; and

a single clutch collar having teeth on a surface of said collar wherein said clutch collar teeth selectively engage with said first axle half shaft teeth and said second axle half shaft teeth and said clutch collar teeth selectively engage with said third set of teeth on said rear case;

wherein said rear case does not have a differential.

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